IDENTIFICATION OF THE SURFACE ROUGHNESS-STATE VARIABLES RELATION AND ITS APPLICATION TO THE HIGH-SPEED MACHINING CONTROL

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ABSTRACT

In this paper surface roughness, obtained by machining with different cutting speeds, is analyzed. A special experimental device was developed for this. Surface roughness was investigated using digitally device Surtronic 3+ and was analyzed with specific software Talyprofile. Materials used for this study of roughness at high speed machining conditions where six brands of high and medium alloyed steels, machined with two different cutting feeds and six different cutting speeds. Transversal profile of the asperity was investigated, and was established the minimum chip thickness. Longitudinal profile of the asperity was, also, established. At the end we proposed a modified cutting tool and modified cutting model in order to obtain the minimum of the surface roughness, applicable to the high speed turning finishing of machined surfaces.

KEYWORDS: high speed machining control, surface roughness, state variables, identification.

1. INTRODUCTION

High speed machining, is one of the modern technologies which, in comparison to conventional speed machining, allow high metal removal rate, considerably increase in productivity, increased surface finishing and eliminate cooling. It leads to shortening the manufacturing time, some processing step elimination (manual manufacturing) and has no influence on dimensional precision and surface quality. These advantages are decisive for using high speed machining in different industrial fields under special conditions.

High-speed machining processes has been known for relatively long time, but there is still needed further research in order to further improve parts' quality and to reduce machining costs.

The machining features, which are hallmark of super alloys, are: involvement of multiple wear mechanisms in cutting tool failure, considerable damage to machined surfaces, which extends to the sub-surface levels in some cases, and involvement of intense shear in the chip formation [1, 2].

The machined surface characteristics such as surface roughness and surface damage have significant influence on the surface sensitive properties such as fatigue, stress, corrosion resistance and creep strength, which in turn affect the service-life of components [3]. Therefore, high degree of surface integrity is an essential requirement for better performance, reliability and longevity of the machined parts during service. The cutting forces have an important contribution to the generation of stress and temperature in the machined surfaces. They further influence the stress and temperature along tool-chip and tool-work interfaces. All these effects finally lead to poor surface integrity unless the working conditions are properly selected. Therefore, it is important to know the machining parameters, which reduce cutting forces and generate favourable surface characteristics.

The surface generated during machining has been a subject of research of a number of investigations. These include analysis and/or evaluation of surface finish, surface alterations [5, 8, 10, 13÷17].

Besides, it is demonstrated that the cutting tool edge geometry significantly influences many fundamental machinability factors such as cutting forces, chip generation, cutting temperature, tool wear, tool-life and characteristics like surface roughness and surface damage [10, 11, 16, and 17].

It appears that most of the work has been done at reasonably lower cutting speeds, whereas the increasing use of materials in different conditions and industries necessitates the knowledge of their machinability properties at higher cutting speeds, which is not adequate at the present. Further, less attention has been paid to optimize the process parameters to improve machinability in terms of cutting forces and surface integrity of machined materials. Also, most of these studies include random experiments.

Thus, in this experimental work, turning process is selected to assess the effect of edge geometry and machining parameters on the surface integrity. The surface quality in terms of surface roughness and surface damage has also been investigated.

The following sections of this paper describe the plan of the experiments and their execution followed by the analysis of the results.

2. EXPERIMENTAL DEVICE

In order to realise the experimental study of the surface roughness generated by high speed machining, it was designed and built the following experimental device presented in Fig. 1:

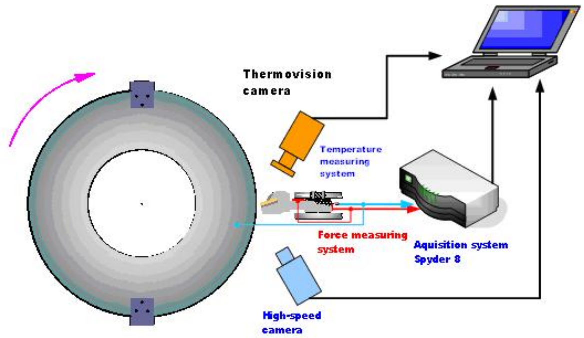

Fig.1. Experimental device for the study of high speed machining

The disc of the device is made of a steel base with a 500 mm diameter, placed on the chuck of the numerical controled frontal lathe.

On this disc two opposite channels weres machined, with the dimensions of 60x40x3mm, in which the analyzed samples were located. These samples were attached with three M10 screws. The whole device is protected against accidental detachment from the lathe axis.

The cutting speed obtained, while the main axis of the lathe revolves at a speed of 1400 rot/min, is 36,6 m/s.

The tool used was a lathe tool offered by the Sandvik company, model ISO DVJNL 2020K16 fitted with Garant brand insertions made of metallic carbide (HB712) and with cubic boron nitride (CBN 725) respectively.

Materials used for the study of roughness when processed at high speed are six brands of high and medium alloyed steels: 42CrMo4, OLC45, 20TiMnCr12, 34MoCrNi16, 18MnCr11, 41Cr4.

From these materials, samples are made having the dimensions of 60x60x25 mm, which are future machined using two types of cutting inserts; an insert of metallic carbide Garant brand with grade HB712, and another insert having the edge made of cubic boron nitride (CBN), still Garant brand, grade CBN725. Each of the selected work materials were machined with both cutting tools, employing two feeds and, respectively, six cutting speeds.

The cutting speed was chosen adequately in order to comparatively study both the field of conventional cutting and also the field of high speed cutting. The maximum speed employed is conditioned by the maximum revolution that the lathe can generate.

The roughness was measured using the digital device Surtronic 3+ and the profilegrams were obtained by using the Talyprofile software, thus enabling the computing of the various profile parameters.

Several parameters of the cutting process were investigated such as, cutting force, temperature, etc. in order to establish a strong relation between surface roughness and state variables.

3. RESULTS ANALYSIS

One important aspect of roughness is the generation of roughness, occurring mainly due to two important conditions:

- Generating profile of the tool,
- Micro profile of the cutting edge.

We shall further present the experimental study of generated roughness occurring due to the cutting tool profile which, while turning, results in the occurrence of some tracks on the processed surface. These tracks had a transversal profile, specific for the cutting edge and located at a distance that was equal to the feed (fig. 2).

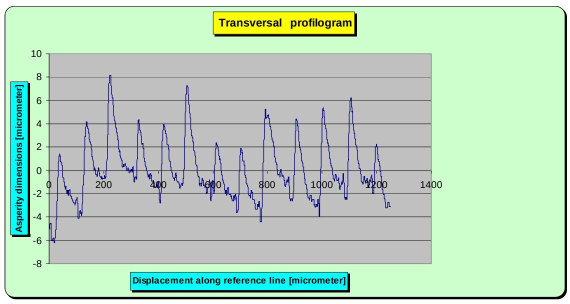

Fig.2. Typical aspect of a transversal profile obtained during experiments

The transversal profile was investigated for the surface obtained using various cutting speeds and for various tool and work materials.

In order to study the generated roughness of the cut surface, the profile of roughness along the movement direction of the cutting tools was analyzed (Fig.3.).

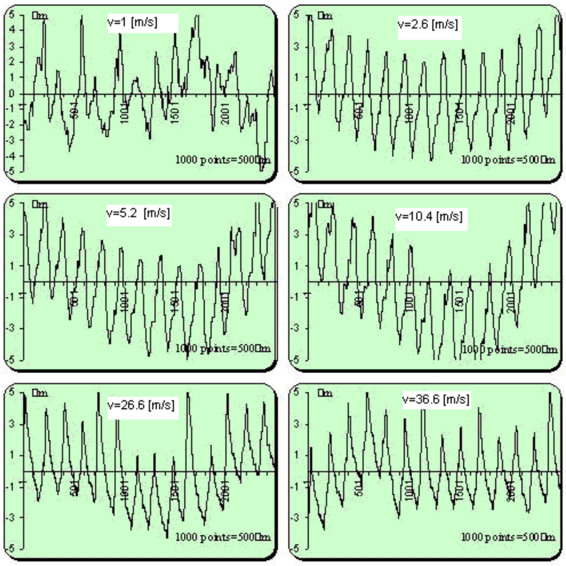

Fig.3. Variation of the transversal profile in accordance with the cutting speed

It can be seen that the variation level of the profile rises towards the direction where the tool movement decreases with the cutting speed. This is due to the fact that the random phenomena generated at lower cutting speed are subsequently replaced with plastic deformation phenomena, the chip being ultimately the results of a pure plastic deformation.

The following observations can be advanced.

It is remarkable the exact pattern in which the transversal profile is generated along the tool feed movement direction, which shows that there are only few random aspects that may interfere when generating this profile.

Also, it can be seen that there is a difference of the relative position between two successive profiles, which is explained by different shock behaviour of the experimental system.

Large scale evolution of the transversal profile position may be due to the measurement system, as the measurement reference moves along the touched surface.

The height of profile edges are significantly altered along the surface exploration movement, and are not rigorously correlated with height alterations for each profile base. This suggests the fact that there are random phenomena while forming this area of the transversal profile.

In order to develop a detailed study of the transversal profile, this profile was examined in various areas of the surface and compared with the theoretical profile of the generating edge of

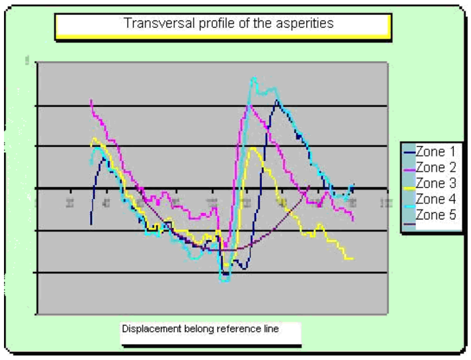

Fig.4. Transversal profile of roughness in various surface areas

the tool, as it can be seen in Fig.4

It can be seen that an area of the profile looks very close to the shape of the theoretical profile, which shows that within the respective area do not occur phenomena leading to the profile copy disturbance, and even of the cutting edge micro profile disturbance, on the cut surface.

In exchange, the other area of the profile drastically differs from the theoretical profile and, moreover, is significantly differs from one area to another. This supports the idea that the respective area of the profile is not generated by the geometry and by the micro geometry of the cutting edge, but is the result of a plastic deformation process, influenced by random phenomena. This also explains the significant variation of the profile height in various areas, which was noticed in Fig.2 as well.

3.2 Minimal chip thickness

With a view of explaining the differences between the real and the theoretical transversal profiles, the connection between these differences, the variation of the thickness of the detached chip was analyzed. In Fig. 5 it can be seen that the differences always occur in the CB area of the theoretical profile and corresponds to the area in which the chip thickness takes very small values tending to zero. Indeed, as it results from Fig. 5, the shape and the dimensions of the theoretical chip greatly varies, and this happens predominantly in the area in which the tool profile generates the transversal profile of surface roughness. Taking into account that the tool edge is not perfectly sharp, as it is the result of the joining of the evolving side towards the facing side with a radius of 5 μm, then it results on the occurrence of a situation in which the thickness of the theoretical chip is smaller than the joining radius of the cutting edge. It is apparent that in this situation the material will not advance towards the chip, but it will be crushed and forced to advance below the cutting edge. By examining the real case of laboratory experiments, it can be seen that it is a good correspondence between the C point located on the theoretical profile, where the theoretical thickness of the chip can be compared to the cutting radius of the cutting edge, and the point in which the dimension of the transversal profile begins. It can be concluded that there is an area CB of *q* width, where the cutting is replaced by ramming.

The thickness of the theoretical chip corresponding to the C point will be referred to as minimal chip thickness.

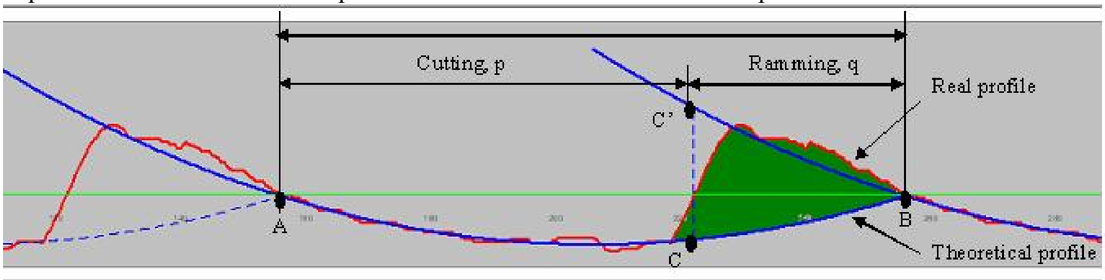

Fig.5. Correspondence between the real and the theoretical profile represented by the values close to vertical and horizontal scaling

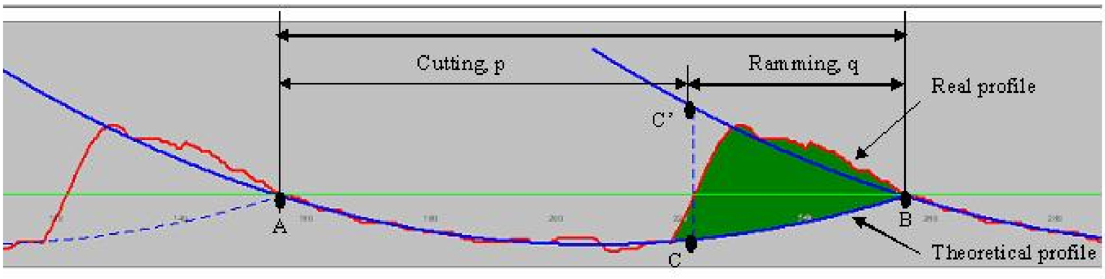

Fig.5. Correspondence between the real and the theoretical profile represented by the values close to vertical and horizontal scaling

It was experimentally studied the variation of the minimal thickness of the chip with the cutting speed (fig. 6.).

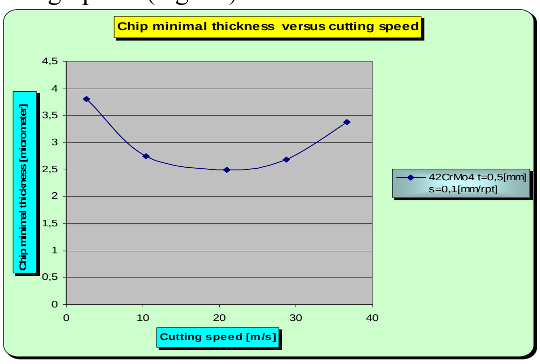

Fig.6. Variation of the minimal thickness of the chip, compared to the cutting speed

It can be noticed that there is an optimal value of the cutting speed in which the cutting edge has the capability to cut thin layers of material, the smallest value of the minimal thickness reaching the value of 2,5 μm.

3.3 Longitudinal profile of the asperity

In order to study cutting roughness, the profile of the asperities in the speed direction of the work piece was analyzed.

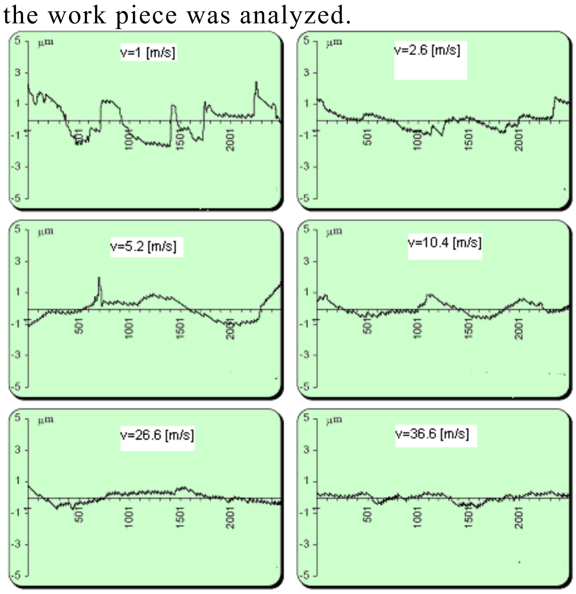

Fig.7. Variation of the longitudinal profile in accordance with the cutting speed

It is observed that with increasing of cutting speed the roughness profile variation level in direction of tool movement is decreasing. That is happening because of random aspects of chip formation which characterise machining at low speed are been replaced by plastic deformation phenomena, the chip being made only by pure plastic deformation.

As we have shown above, the total surface roughness is given mostly by transversal roughness while the longitudinal roughness given by cutting process has a relatively small influence.

Thus, to control surface roughness one must increase the cutting speed and to operate with a cutting tool having a special geometry.

To test the finishing possibility of the high speed cutting, on the basis of the results obtained within our research, it was proposed a finishing process by turning, in accordance with the cutting diagram presented in Fig. 8

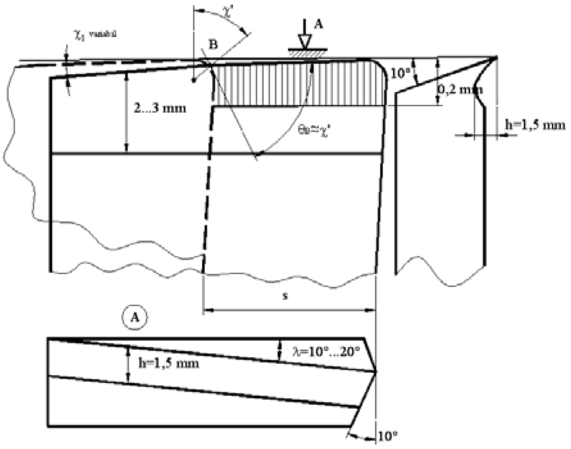

Fig.8. Cutting diagram for surface finishing by high speed cutting

In Fig. 8 are presented two successive positions of a lathe tool with modified geometry. To obtain finishing by high speed cutting, the tool positions has been successively positioned at a distance equal to the feed, s. The χ_1 angle takes very small values. In this case the chip thickness has the value of 0.2 mm, and the width is equal to the feed rate value, which in the case under focus is of 0.3 - 0.5 mm/rev.

In Fig.9 is presented the transversal profile of roughness obtained by machining with modified cutting tool. It is observed that by variation of χ_1 angle transversal profile of the roughness is influenced only by microprofile of cutting edge and not by geometrical profile of him. The results are Ra=0.199 µm and Rz=1.42 µm. Thus, for the next decreasing of surface roughness it must to carefully finishing the cutting edge

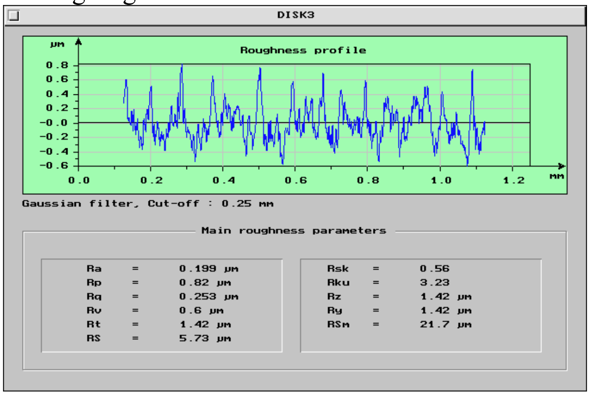

Fig.9. Transversal profile roughness obtained by machining with modified cutting tool

4. CONCLUSIONS

The conclusions drawn for surface finishing by high speed turning are the following:

1. Surface finishing by high speed cutting is possible up to Ra=0.2 µm.
3. The cutting speed can be increased, thus highlighting the adiabatic character of cutting.
4. By high speed cutting and careful finishing of the tool cutting edge, it can be obtained a machined surface with significantly decreased roughness similar with those obtained by grinding.

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